Claims

1. An electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about 220°C to about 550°C.

2. An electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about 175°C to about 550°C, said electronically insulating proton conductor containing no acid-containing liquid phase.

3. A proton conducting composite membrane comprising an electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about 220°C to about 550°C.

4. A proton conducting composite membrane comprising an electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about 175°C to about 550°C, said electronically insulating proton conductor containing no acid to maintain conductivity.

5. A membrane electrode assembly comprising an electronically insulating proton conductor and being capable of converting chemical energy of a reaction into electrical energy at a temperature of about 220°C to about 550°C.

6. A membrane electrode assembly comprising an electronically insulating proton conductor and being capable of converting chemical energy of a reaction into electrical energy at a temperature of about 175°C to about 550°C, said membrane electrode assembly contains no acid to maintain conductivity.

7. A membrane electrode assembly comprising a metal hydride support and an electronically insulating proton conductor on said metal hydride support.

8. The membrane electrode assembly of claim 7, wherein said electronically insulating proton conductor is catalyzed.

9. A fuel cell comprising an electronically insulating proton conductor, said fuel cell being capable of converting chemical energy of a reaction into electrical energy at a temperature of about 220°C to about 550°C.

10. The fuel cell of claim 9, further comprising a metal hydride.

11. The fuel cell of claim 9, further comprising a mixed conductor capable of conducting electrons and protons.

12. The fuel cell of claim 9, wherein the fuel cell is capable of reforming a chemical entity into another chemical entity.

13. The fuel cell of claim 9, wherein the fuel cell comprises a reforming catalyst.

14. A fuel cell comprising an electronically insulating proton conductor, said fuel cell being capable of converting chemical energy of a reaction into electrical energy at a temperature of about 175°C to about 550°C, said electronically insulating proton conductor containing no acid to maintain conductivity.

15. The fuel cell of claim 14, further comprising a metal hydride.

16. The fuel cell of claim 14, further comprising a mixed conductor capable of conducting electrons and protons.

17. The fuel cell of claim 14, wherein the fuel cell is capable of reforming a chemical entity into another chemical entity.

18. A fuel cell comprising electrodes and means, responsive to exposure of at least a chemical entity, for converting chemical energy of a reaction into electrical energy at a temperature of about 220°C to about 550°C.

19. A fuel cell comprising electrodes and means, responsive to exposure of at least a chemical entity, for converting chemical energy of a reaction into electrical energy at a temperature of about 175°C to about 550°C, said electronically insulating proton conductor containing no acid to maintain conductivity.

20. A system for generating electricity, comprising a fuel reformer and a fuel cell, said fuel cell being capable of converting chemical energy of a reaction into electrical energy at a temperature of about 220°C to about 550°C.

21. The system of claim 20, wherein the fuel reformer is a syngas generator.

22. The system of claim 20, wherein the fuel reformer comprises a reforming catalyst in the fuel cell and/or an external reformer.

23. The system of claim 20, further comprising a water gas shift reactor.

24. The system of claim 23, further comprising an oxidation unit.

25. A system for generating electricity, comprising a fuel reformer and a membrane electrode assembly comprising an electronically insulating proton conductor, said membrane electrode assembly being capable of converting chemical energy of a reaction into electrical energy at a temperature of about 175°C to about 550°C, said electronically insulating proton conductor containing no acid to maintain conductivity.

26. The system of claim 25, wherein the fuel reformer is a syngas generator.

27. The system of claim 25, wherein the fuel reformer comprises a reforming catalyst in a fuel cell and/or an external reformer.

28. The system of claim 25, wherein the syngas generator is capable of generating hydrogen.

29. The system of claim 25, further comprising a water gas shift reactor.

30. The system of claim 29, further comprising an oxidation unit.

31. The electronically insulating proton conductor of claim 1 or 2, wherein the electronically insulating proton conductor is selected from the group consisting of $Ba_3Ca_{1.18}Nb_{1.82}O_{8.73}$-$H_2O$ (BCN 18); CsH_2PO_4 (CDP); $Sr[Zr_{0.9}Y_{0.1}]O_{3-\delta}$ (SZYO); polyphosphate composite containing19.96 wt% NH_4^+, 29.3 wt% P, 1.51 wt% Si; $La_{0.9}Sr_{0.1}Sc_{0.9}Mg_{0.1}O_3$ (LSSM); and $BaCe_{0.9-x}Zr_xM_{0.1}O_{3-\delta}$ where M is Gd or Wd and x = 0 to 0.4 (BCZMO).

32. The proton conducting composite membrane of claims 3 or 4, further comprising a metal hydride substrate.

33. The proton conducting composite membrane of claim 32, wherein the metal hydride is selected from the group consisting of Pd, a Pd alloy, V/Ni/Ti, V/Ni, V/Ti, PdAg, PdCu, Ti, $LaNi_5$, TiFe and CrV_2.

34. The membrane electrode assembly of claim 5, 6 or 7, further comprising an anode and a cathode.

35. The membrane electrode assembly of claim 34, wherein the anode and/or the cathode comprises a noble metal and/or a non-noble metal.

36. The membrane electrode assembly of claim 34, wherein the anode and/or the cathode comprises a layer capable of allowing diffusion of a gas and conduction of electrons.

37. The membrane electrode assembly of claim 36, wherein the layer is selected from the group consisting of a carbon cloth and a metal cloth.

38. A method for converting chemical energy of a reaction into electrical energy, comprising exposing an electronically insulating proton conductor to a chemical entity at a temperature of about 220°C to about 550°C, and generating electromotive force (emf) across the electronically insulating proton conductor.

39. The method of claim 38, further comprising exposing the electronically insulating proton conductor to an oxidant.

40. The method of claim 38, further comprising producing the chemical entity by reforming another chemical entity.

41. A method for converting chemical energy of a reaction into electrical energy, comprising exposing an electronically insulating proton conductor to a

chemical entity at a temperature of about 175°C to about 550°C, and generating electromotive force (emf) across the electronically insulating proton conductor; wherein said electronically insulating proton conductor contains no acid to maintain conductivity.

42. The method of claim 41, further comprising exposing the electronically insulating proton conductor to an oxidant.

43. The method of claim 41, further comprising producing the chemical entity by reforming another chemical entity.

44. An electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

45. An electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than

said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540, said electronically insulating proton conductor containing no acid-containing liquid phase.

46. A proton conducting composite membrane comprising an electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

47. A proton conducting composite membrane comprising an electronically insulating proton conductor of a membrane electrode assembly that is capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540,

said electronically insulating proton conductor containing no acid to maintain conductivity.

48. A membrane electrode assembly comprising an electronically insulating proton conductor and being capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

49. A membrane electrode assembly comprising an electronically insulating proton conductor and being capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540, said membrane electrode assembly contains no acid to maintain conductivity.

50. A fuel cell comprising an electronically insulating proton conductor, said fuel cell being capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

51. A fuel cell comprising an electronically insulating proton conductor, said fuel cell being capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540, said electronically insulating proton conductor containing no acid to maintain conductivity.

52. A fuel cell comprising electrodes and means, responsive to exposure of at least a chemical entity, for converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of

220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

53. A fuel cell comprising electrodes and means, responsive to exposure of at least a chemical entity, for converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540, said electronically insulating proton conductor containing no acid to maintain conductivity.

54. A system for generating electricity, comprising a fuel reformer and a fuel cell, said fuel cell being capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

55. A system for generating electricity, comprising a fuel reformer and a membrane electrode assembly comprising an electronically insulating proton

conductor, said membrane electrode assembly being capable of converting chemical energy of a reaction into electrical energy at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540, said electronically insulating proton conductor containing no acid to maintain conductivity.

56. A method for converting chemical energy of a reaction into electrical energy, comprising exposing an electronically insulating proton conductor to a chemical entity at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530 and 540.

57. A method for converting chemical energy of a reaction into electrical energy, comprising exposing an electronically insulating proton conductor to a chemical entity at a temperature of about X°C to about Y°C, wherein said Y is greater than said X, and said X and said Y are selected from the group consisting of 175, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500,

510, 520, 530 and 540; wherein said electronically insulating proton conductor contains no acid to maintain conductivity.

58. The membrane electrode assembly of claim 5, 6 or 7, wherein the membrane electrode assembly has an area specific resistance in a range of about 0.01 to about 100 $ohm.cm^2$.

59. The fuel cell of claim 9 or 14, wherein a membrane electrode assembly has an area specific resistance in a range of about 0.01 to about 100 $ohm.cm^2$.

60. The fuel cell of claim 9, wherein a membrane electrode assembly has an area specific resistance of a material having a thickness of about 175 microns and a proton conductivity within the gap of Figure 1.

61. The fuel cell of claim 14, wherein a membrane electrode assembly has an area specific resistance of a material having a thickness of about 175 microns and a proton conductivity within the gap of Figure 2.

62. The system of claim 20, wherein the syngas generator is capable of generating hydrogen.